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STUDY OF THE TWOPHOTON PHOTOREFRACTIVE EFFECT IN LITHIUM NIOBAT--ETC(U)
OCT 81 V E WOOD, C M VERBER, R C SHERMAN   DAAG29-78-C-0028
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The dynamics and wavelength dependence of recording and optical erasure of thick phase gratings produced photorefractively were studied in undoped and in iron-doped lithium niobate. Properties of gratings formed at high incident power densities via two-photon absorption were compared with those of gratings formed at shorter wavelengths by the usual one-photon mechanism. Gratings formed by the two-photon mechanism in undoped crystals exhibit a distinctive two-exponential time dependence of optical erasure not observed in other circumstances. This shows that the nature of final trap states, as well

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as absorption and charge transfer characteristics, is important in controlling photorefractive sensitivity. A method was discovered for producing high diffraction efficiency gratings at infrared frequencies in titanium-diffused optical waveguides on lithium niobate.

STUDY OF THE TWO-PHOTON PHOTOREFRACTIVE EFFECT IN LITHIUM NIOBATE

FINAL REPORT

by

Van E. Wood, Carl M. Verber,
Rand C. Sherman and Nile F. Hartman

October 26, 1981

U.S. ARMY RESEARCH OFFICE

Contract DAAG-29-78-C0028

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

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STATEMENT OF PROBLEM AND PRINCIPAL RESULTS

Photorefractivity is the name given to the spatially-varying change in refractive index which occurs in certain non-centrosymmetric crystals and poled ceramics when they are exposed to a spatially inhomogeneous light beam of suitable frequency and intensity. Since such a phenomenon is deleterious in some applications, the effect is sometimes referred to as "optical damage", a term which is, however, also applied to other effects. In the present program, we have studied the dynamics and the wavelength dependence of the photorefractive formation and optical erasure of thick phase gratings in lithium niobate, a material widely used in optical modulators, detectors, and data-processing devices and in integrated optics. Both nominally pure and iron-doped crystals have been investigated; and effects produced by ordinary (one-photon) optical absorption have been compared with those produced at high light intensities by two-photon absorption through a virtual intermediate state. The two-photon effect has been suggested as a possible way of forming holographic beam-splitters, modulators, etc., in a wavelength region where the crystal is completely transparent at low intensitites, and thus immune to further photorefractive changes during use. Photorefractive effects occurring in optical waveguides made by diffusion of titanium into lithium niobate have also been studied and contrasted with those occurring in the bulk. The results have been reported in a series of presentations and papers, some of which are still in preparation.

It was demonstrated that two-photon photorefractivity could be observed and separated from one-photon effects at moderate peak power densities (~10 MW/cm^2) using repetitively pulsed lasers. We showed that the photorefractive sensitivity in iron-doped lithium niobate was considerably greater than that in undoped crystals. Photorefractive holographic gratings recorded in iron-doped $LiNbO_3$ by the two-photon process show similar optical erasure characteristics — a simple exponential decay, roughly inversely proportional to light intensity — to those recorded in the same crystals at shorter wavelengths using the one-photon effect, indicating that whatever the recording process, the same trap states end up being filled. The situation is quite different, though, in undoped $LiNbO_3$; there two-photon gratings display a distinct two-exponential optical erasure characteristic, while gratings recorded by the one-photon mechanism had a single exponential decay similar to that in the doped crystals.

Considerable interest attaches to the possibility of forming holographic gratings at long wavelengths in optical waveguides, as well as to the generation of long-term optical damage in devices using such waveguides. We found that gratings could be formed using 1.06 μm external-wavelength beams in waveguides produced by diffusion of titanium into $LiNbO_3$, provided the grating was previously "sensitized" by exposure to guided light of 0.633 μm-wavelength from a He-Ne laser. Gratings could also be written at 1.06 μm without the sensitization step if the peak power was sufficiently high; but the power densities were then such as sometimes to produce physical damage to the waveguide. A two-photon, two-step process may be involved in both the sensitized and the high-power grating formation methods. While some evidence of optical damage in waveguides at long wavelengths may have been seen in other experiments, we believe those are the first high (25%) diffraction efficiency gratings produced by a photorefractive mechanism at 1.06 μm.

Presentations

1. V. E. Wood, "Two-photon photorefractivity in pure and doped $LiNbO_3$". IEEE International Symposium on Applications of Ferroelectrics, Minneapolis, MN, June 1979.

2. V. E. Wood, "Optical erasure of one- and two-photon holograms in lithium niobate". Fifth International Meeting on Ferroelectricity, State College PA, August 1981.

Publications

1. V. E. Wood, N. F. Hartman and C. M. Verber, "Two-photon photorefractivity in pure and doped $LiNbO_3$". Ferroelectrics, 27, 237, (1980).

2. V. E. Wood, R. C. Sherman, N. F. Hartman and C. M. Verber, "Optical erasure of one- and two-photon holograms in Fe-doped $LiNbO_3$". Ferroelectrics, 34, 175 (1981).

3. V. E. Wood, R. C. Sherman and C. M. Verber, "Hologram formation at 1.06 μm in $LiNbO_3$:Ti optical waveguides". Manuscript in preparation for submission to *Optics Communications*.

4. V. E. Wood, R. C. Sherman and C. M. Verber, "Optical erasure of one- and two-photon holograms in undoped $LiNbO_3$". Manuscript in preparation for submission to *Ferroelectrics*.

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Carl M. Verber
Van E. Wood
Nile F. Hartman
Rand C. Sherman

Degrees granted

None. Battelle is not a degree-granting institution.

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